National Cooperative Dairy Herd Improvement Program

RECORD BOOK

A plan for every size herd

OFFICIAL DHIA OWNER SAMPLER WEIGH-A-DAY-A-MONTH

AGRICULTURAL RESEARCH SERVICE, U. S. DEPARTMENT OF AGRICULTURE

ARS-44-207

Dairy-Herd-Improvement Letter (Vol. 44, No. 6)

December 1968

THE PROBABILITY FOR DETERMINING WHICH OF TWO BULLS HAS A SUPERIOR GENETIC MERIT

by B. T. McDaniel, F. R. Allaire[1/], and F. N. Dickinson

Dickinson 2/ has shown that daughters of bulls with high plus Predicted Differences (PD) for milk yield return more dollars of income over feed cost than progeny of bulls with lower and minus PD's. This means higher production and more profits for dairymen milking daughters of bulls with high PD's. Also, McDaniel 3/ has shown that daughters of high PD bulls eat more forage and are better feed converters. Since PD is really the best estimate of a bull's genetic transmitting ability for production, dairymen can increase their production and profits by using genetically superior bulls chosen on PD.

Bulls, of course, differ considerably in their level of true genetic transmitting ability. Also, the estimate of

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1/ Dairy Department, The Ohio State University, Columbus.
2/ Dickinson, Frank. Daughters of high "PD" sires can add $1,600 income to a 50-cow herd. Hoard's Dairyman. September 10, 1968.
3/ McDaniel, Ben. Bulls with a high "PD" sire better cattle. Hoard's Dairyman. September 10, 1968.

Issued January 1969

true genetic transmitting ability, the PD, will vary somewhat in its reliability due to the sampling nature of inheritance and various factors that affect the lactation records used in its calculation. These factors have been described by Plowman 4/. The accepted measure of reliability of the PD is termed "Repeatability." This Repeatability value is actually a regression factor used to adjust the calculated daughter-herdmate difference according to the confidence that can be placed on the PD as an accurate estimation of true genetic transmitting ability.

In most cases it is simple for dairymen to separate bulls that are real breed improvers from those that will probably lower production a great deal. However, dairymen have more difficulty in selecting the bulls to use in their herds from among a group of breed improvers. The main source of this difficulty arises from trying to choose between two bulls that have widely differing Repeatability factors on their PD's. Many dairymen hesitate or even refuse to use bulls in their herd that have low Repeatabilities no matter how high the PD's of those bulls may be. Frequently, they feel that a low Repeatability inherently means that the PD is inaccurate or even grossly biased. All evidence indicates that the best use of Repeatability is as a guide to how much you should use any individual bull. A concerted educational effort by Extension Dairymen, AI organizations, breed associations, farm publications, and USDA has largely overcome this misunderstanding of the term "Repeatability." If you have questions on the proper use of Repeatability, please refer to the article by Dickinson and McDaniel 5/.

Dairymen often ask, "How do I judge whether a specific bull has a higher true genetic transmitting ability than another specific bull if they have different PD's and Repeatabilities?" Procedures for making such a decision have recently been developed by F. R. Allaire and were reported

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4/ Plowman, R. D. Notes and concepts used in USDA sire summary procedures. U.S. Department of Agr., Dairy Herd Impr. Letter. April 1968.

5/ Dickinson, Frank N., and B. T. McDaniel. How to use the new Repeatability factor when picking sires for your herd. Hoard's Dairyman. September 10, 1968.

at the 1968 meeting of the American Dairy Science Association 6/. These procedures can be used to compute the probability that one bull is superior to another bull in true genetic transmitting ability, given the PD's and Repeatabilities of the two bulls in question.

Tables and procedures based on Allaire's work are included here and can be used by dairymen to determine the probability, or odds, that any one bull has a true genetic transmitting ability superior to that of any other bull. Taken into account in these tables are the breed of the bulls, their individual Repeatabilities, and the amount that the PD of the higher bull exceeds the PD of the lower bull.

The probabilities in table 1 should be used for comparing bulls of the Ayrshire, Guernsey, and Jersey breeds for milk yield. The probabilities in table 2 should be used for comparing bulls of the Holstein and Brown Swiss breeds. These divisions are based on USDA research 7/ showing that the variation among bulls of the first three breeds is about 400 pounds of milk, and that the variation among bulls of the latter two breeds is about 550 pounds of milk.

The probabilities in table 3 can be used to compare bulls of all the dairy breeds on their ability to transmit fat yield.

For those who prefer to think of these probabilities in terms of odds, the tabulation on the following page shows the relation between probabilities expressed as percents and as odds.

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6/ Allaire, F. R. Probabilities arising from dairy sire evaluation models. Jour. of Dairy Sci. 51:958, and mimeographed handout, 4 p. 1968.

7/ McDaniel, B. T., and R. D. Plowman. Distributions of Predicted Differences by milk in the dairy breeds. 1967. (Unpublished.)

Percent	Odds	Percent	Odds
50	1:1	80	4:1
55	6:5	83	5:1
57	4:3	86	6:1
60	3:2	89	8:1
63	5:3	90	9:1
67	2:1	91	10:1
70	7:3	94	15:1
75	3:1	96	20:1

In using these tables the assumption is made that the daughters of the bulls being compared received the same feeding and managemental care as did other cows in the same herds. If preferential treatment has affected the records of the daughters of either of the bulls being compared, the probabilities in these tables will not be correct. The error in the probability will be directly proportionate to the bias in the PD. However, research results obtained by USDA 8/ and at Cornell University 9/ have indicated that in the vast majority of cases preferential treatment has not caused serious biases in PD of low Repeatability.

To use these probability tables, obtain the PD and the Repeatabilities of the two bulls that are to be compared and use the following procedures:

First, compute the superiority of the PD of the higher bull in pounds (i.e., higher PD minus lower PD). That difference in the PD will tell you which column of table 1 or table 2 to look in (or table 3 if you are comparing PD's for fat).

Second, select the row you should look across according to the Repeatabilities of the two bulls.

Third, find the place in the table where the column that you are looking down intersects with the row that you are looking across. The figure at that

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8/ McDaniel, B. T. Unpublished research on relation between initial and later sire summaries. 1964.

9/ Meek, A. M., and L. D. Van Vleck. Relations between sire proofs. Jour. of Dairy Sci. 47:642-645. 1964.

point in the table is the probability that the bull with the higher PD is superior in true genetic transmitting ability to the bull with the lower PD.

It does not matter which of the bulls has the higher Repeatability. Thus, if one bull has a 20 percent Repeatability and the other bull has a 60 percent Repeatability you would look in the row that corresponds to a 20 percent Repeatability for "lower" and a 60 percent Repeatability for "higher."

Here is an example of steps to follow in using this procedure. Suppose you are trying to judge between two Holstein bulls, which we will call Bull A and Bull B, and their summaries are as follows:

Bull A

PD for milk yield = +307 pounds
Repeatability = 60 percent

Bull B

PD for milk yield = +457 pounds
Repeatability = 20 percent

Step 1: Subtract the PD of Bull A from the PD of Bull B, which equals 457 - 307 or 150 pounds. Then find the column in table 2 with the heading 150.

Step 2: Find the row that corresponds most closely to a 20 percent Repeatability for the "lower" Repeatability and a 60 percent Repeatability for the "higher."

Step 3: Now look down the column with the heading 150 and across the row labeled 20 and 60 percent to the point where they intersect. You will figure out that the point of intersection is 59, which means that the probability that the bull with the higher PD (Bull B) has a higher true genetic transmitting ability than the bull with the lower PD (Bull A) is 59 percent.

If you wish to convert 59 percent to odds, referral to the tabulation at the top of page 4 will indicate that

59 percent probability is approximately equivalent to 3:2 odds that Bull B has a higher true genetic transmitting ability for milk production than does Bull A.

It is not practical, nor is it necessary, to show all possible combinations of Repeatabilities and differences between bulls because this would result in tables too large and too numerous for practical use. Comparisons that fall between the values listed in these tables can be safely made without much error by using the closest figures that appear on the tables. The probabilities obtained by this procedure will be very close to the true probability.

CALCULATION OF EXACT PROBABILITIES

For those who wish to calculate the exact probabilities, a computing version of Allaire's formula is as follows:

$$\text{Table value} = \frac{\text{PD (high) minus PD (low)}}{\text{Breed std.dev.} \times \sqrt{2.00 - \text{Rept.(high)} - \text{Rept.(low)}}}$$

For this calculation, Repeatability (Rept.) is expressed as a decimal proportion instead of a percent (i.e., 20 percent = 0.20; 80 percent = 0.80; etc.) The breed standard deviation (breed std. dev.) equals 400 pounds for Ayrshire, Guernsey, and Jersey milk yields, and equals 550 pounds for Holstein and Brown Swiss milk yields. The standard deviation equals 20 pounds for fat yields of all breeds. The probability percentages corresponding to values computed by Allaire's formula appear on the following page.

Table value	Percent of probability
0.01	50
0.02 - .03	51
.04 - .06	52
.07 - .08	53
.09 - .11	54
.12 - .13	55
.14 - .16	56
.17 - .18	57
.19 - .21	58
.22 - .24	59
.25 - .26	60
.27 - .29	61
.30 - .31	62
.32 - .34	63
.35 - .37	64
.38 - .39	65
.40 - .42	66
.43 - .45	67
.46 - .48	68
.49 - .51	69
.52 - .53	70
.54 - .56	71
.57 - .59	72
.60 - .62	73
.63 - .65	74
.66 - .69	75
.70 - .72	76
0.73 - 0.75	77
.76 - .78	78
.79 - .82	79
.83 - .85	80
.86 - .89	81
.90 - .93	82
.94 - .97	83
.98 - 1.01	84
1.02 - 1.05	85
1.06 - 1.10	86
1.11 - 1.15	87
1.16 - 1.20	88
1.21 - 1.25	89
1.26 - 1.31	90
1.32 - 1.37	91
1.38 - 1.43	92
1.44 - 1.51	93
1.52 - 1.59	94
1.60 - 1.69	95
1.70 - 1.81	96
1.82 - 1.96	97
1.97 - 2.17	98
2.18 - 2.39	99

As an example, suppose we have two Holstein bulls with the following summaries:

Bull C: 19 percent Repeatability, +438 PD for milk yield

Bull D: 53 percent Repeatability, +381 PD for milk yield

$$\text{Table value} = \frac{57}{550 \times \sqrt{2.0 - 0.19 - 0.53}}$$

$$= \frac{57}{550 \times \sqrt{1.28}}$$

$$= \frac{57}{550 \times 1.13} = \frac{57}{621.5} = 0.09$$

If we look up 0.09 in the above tabulation, we find a value of 54. Thus, the probability that Bull C is superior to Bull D is 54 percent, or about 7 to 6 odds.

To ease the effort necessary to compute exact probabilities, the proper denominators for various combinations of Repeatabilities, breed, and milk and fat are given in table 4. To find the proper line in the table, merely add the Repeatabilities of the two bulls you are comparing. In our earlier example, on page 12 these would be 60 + 20, or a sum of 80. Looking in table 4 under column 3, we find a value of 602. The rather small changes in the denominators with the increments of 5 percent indicate that the value just below the sum of the Repeatabilities can be used without much error when the sum falls between the increments. In our example on computing exact probabilities, the sum of the Repeatabilities was 72 (19 + 53), and we calculated a denominator of 621.5. Looking in the table for the proper denominator, we find a value of 627, which is quite close.

TABLE 1.--Probability that the bull with the higher Predicted Difference of a pair of Ayrshire, Guernsey, or Jersey bulls has the greater true genetic transmitting ability for milk yield

Repeatability		Superiority of Predicted Difference (PD) on the higher PD bull (pounds) for milk yield												
Lower	Higher	50	100	150	200	250	300	400	500	600	700	800	900	1,000
--- Percent ---		---------- Percent ----------												
20	20	53	57	61	65	68	72	78	83	88	91	94	96	98
	30	54	58	61	65	69	73	79	84	89	92	95	97	98
	40	54	58	62	66	70	73	80	85	89	93	95	97	98
	50	54	58	62	66	70	74	81	86	90	94	96	98	99
	60	54	58	63	67	71	75	82	87	91	94	96	98	99
	70	54	59	63	68	72	76	83	88	92	95	97	98	99
	80	54	59	64	69	73	77	84	89	93	96	98	99	--1/
	90	55	60	65	70	74	78	85	90	94	97	98	99	--
	99	55	60	66	71	75	79	86	91	95	97	99	--	--
30	30	54	58	62	66	70	73	80	85	89	93	95	97	98
	40	54	58	62	66	70	74	81	86	90	94	96	98	99
	50	54	58	63	67	71	75	82	87	91	94	96	98	99
	60	54	59	63	68	72	76	83	88	92	95	97	98	99
	70	54	59	64	69	73	77	84	89	93	96	98	99	--
	80	55	60	65	70	74	78	85	90	94	97	98	99	--
	90	55	60	66	71	75	79	86	92	95	97	99	--	--
	99	55	61	67	72	77	81	88	93	96	98	99	--	--
40	40	54	58	63	67	71	75	82	87	91	94	96	98	99
	50	54	59	63	68	72	76	83	88	92	95	97	98	99
	60	54	59	64	69	73	77	84	89	93	96	98	99	--
	70	55	60	65	70	74	78	85	90	94	97	98	99	--
	80	55	60	66	71	75	79	86	92	95	97	99	--	--
	90	55	61	67	72	77	81	88	93	96	98	99	--	--
	99	56	62	68	74	79	83	90	94	97	99	--	--	--
50	50	54	59	64	69	73	77	84	89	93	96	98	99	--
	60	55	60	65	70	74	78	85	90	94	97	98	99	--
	70	55	60	66	71	75	79	86	92	95	97	99	--	--
	80	55	61	67	72	77	81	88	93	96	98	99	--	--
	90	56	62	68	74	79	83	90	95	97	99	--	--	--
	99	56	63	70	75	81	85	92	96	98	99	--	--	--
60	60	55	60	66	71	75	79	86	92	95	97	99	--	--
	70	55	61	67	72	77	81	88	93	96	98	99	--	--
	80	56	62	68	74	79	83	90	95	97	99	--	--	--
	90	56	63	70	75	81	85	92	96	98	99	--	--	--
	99	57	65	72	78	83	88	94	97	99	--	--	--	--
70	70	56	62	68	74	79	83	90	95	97	99	--	--	--
	80	56	63	70	75	81	85	92	96	98	99	--	--	--
	90	57	65	72	78	83	88	94	98	99	--	--	--	--
	99	58	67	75	81	87	91	96	99	--	--	--	--	--
80	80	57	65	72	78	83	88	94	98	99	--	--	--	--
	90	58	67	75	82	87	91	96	99	--	--	--	--	--
	99	60	70	79	86	91	95	99	--	--	--	--	--	--
90	90	60	71	79	86	92	95	99	--	--	--	--	--	--
	99	64	77	87	93	97	99	--	--	--	--	--	--	--
99	99	81	96	99	--	--	--	--	--	--	--	--	--	--

1/ Dashes indicate probability over 99 percent.

TABLE 2.--Probability that the bull with the higher Predicted Difference of a pair of Holstein or Brown Swiss bulls has the greater true genetic transmitting ability for milk yield

Repeatability		Superiority of Predicted Difference (PD) on the higher PD bull (pounds) for milk yield												
Lower	Higher	50	100	150	200	250	300	400	500	600	700	800	900	1,000
--- Percent ---		Percent												
20	20	52	55	58	61	63	66	71	76	80	84	87	90	92
	30	52	55	58	61	64	67	72	77	81	85	88	91	93
	40	52	56	59	61	64	67	73	77	82	86	89	91	94
	50	52	56	59	62	65	68	73	78	83	86	90	92	94
	60	53	56	59	63	66	68	74	79	84	87	90	93	95
	70	53	56	60	63	66	70	75	80	85	88	91	94	96
	80	53	57	60	64	67	70	76	81	86	90	93	95	96
	90	53	57	61	64	68	71	77	83	87	91	94	96	97
	99	54	58	61	65	69	72	79	84	88	92	95	96	98
30	30	52	56	59	61	64	67	73	77	82	86	89	91	94
	40	52	56	59	62	65	68	73	78	83	86	90	92	94
	50	53	56	59	63	66	68	74	79	84	87	90	93	95
	60	53	56	60	63	66	70	75	80	85	88	91	94	96
	70	53	57	60	64	67	70	76	81	86	90	93	95	96
	80	53	57	61	64	68	71	77	83	87	91	94	96	97
	90	54	58	61	65	69	72	79	84	88	92	95	96	98
	99	54	58	62	66	70	74	80	86	90	93	96	97	98
40	40	53	56	59	63	66	68	74	79	84	87	90	93	95
	50	53	56	60	63	66	70	75	80	85	88	91	94	96
	60	53	57	60	64	67	70	76	81	86	90	93	95	96
	70	53	57	61	64	68	71	77	83	87	91	94	96	97
	80	54	58	61	65	69	72	79	84	88	92	95	96	98
	90	54	58	62	66	70	74	80	86	90	93	96	97	98
	99	54	59	63	67	72	75	82	87	92	95	97	98	99
50	50	53	57	60	64	67	70	76	81	86	90	93	95	96
	60	53	57	61	64	68	71	77	83	87	91	94	96	97
	70	54	58	61	65	69	72	79	84	88	92	95	96	98
	80	54	58	62	66	70	74	80	86	90	93	96	97	98
	90	54	59	63	67	72	75	82	88	92	95	97	98	99
	99	54	59	64	69	73	77	84	90	93	96	98	99	--1/
60	60	54	58	61	65	69	72	79	84	88	92	95	96	98
	70	54	58	62	66	70	74	80	86	90	93	96	97	98
	80	54	59	63	67	72	75	82	88	92	95	97	98	99
	90	54	59	64	69	74	78	84	90	94	96	98	99	--
	99	55	61	66	71	75	80	87	92	95	98	99	--	--
70	70	54	59	63	67	72	75	82	88	92	95	97	98	99
	80	54	59	64	69	74	78	84	90	94	96	98	99	--
	90	55	61	66	71	76	80	87	92	96	98	99	--	--
	99	56	62	68	74	79	83	90	95	97	99	--	--	--
80	80	55	61	66	71	76	80	87	92	96	98	99	--	--
	90	56	63	68	74	79	84	90	95	98	99	--	--	--
	99	57	65	72	78	84	88	94	98	99	--	--	--	--
90	90	58	65	72	79	84	88	95	98	99	--	--	--	--
	99	60	70	79	86	91	95	99	--	--	--	--	--	--
99	99	74	90	97	99	--	--	--	--	--	--	--	--	--

1/ Dashes indicate probability over 99 percent.

TABLE 3.--Probability that the bull with the higher Predicted Difference of a pair of bulls of any breed has the greater true genetic transmitting ability for fat yield

Repeatability		Superiority of Predicted Difference (PD) on the higher PD bull (pounds) for fat yield												
Lower	Higher	50	100	150	200	250	300	400	500	600	700	800	900	1,000
--- Percent ---		Percent												
20	20	57	65	72	78	83	88	91	94	96	98	98	99	--1/
	30	58	65	73	79	84	89	92	95	97	98	99	--	--
	40	58	66	73	80	85	89	93	95	97	98	99	--	--
	50	58	66	74	81	86	90	94	96	98	99	--	--	--
	60	58	67	75	82	87	91	94	96	98	99	--	--	--
	70	59	68	76	83	88	92	95	97	98	99	--	--	--
	80	59	69	77	84	89	93	96	98	99	--	--	--	--
	90	60	70	78	85	90	94	97	98	99	--	--	--	--
	99	60	71	79	86	91	95	97	99	--	--	--	--	--
30	30	58	66	73	80	85	89	93	95	97	98	99	--	--
	40	58	66	74	81	86	90	94	96	98	99	--	--	--
	50	58	67	75	82	87	91	94	96	98	99	--	--	--
	60	59	68	76	83	88	92	95	97	98	99	--	--	--
	70	59	69	77	84	89	93	96	98	99	--	--	--	--
	80	60	70	78	85	90	94	97	98	99	--	--	--	--
	90	60	71	79	86	92	95	97	99	--	--	--	--	--
	99	61	72	81	88	93	96	98	99	--	--	--	--	--
40	40	58	67	75	82	87	91	94	96	98	99	--	--	--
	50	59	68	76	83	88	92	95	97	98	99	--	--	--
	60	59	69	77	84	89	93	96	98	99	--	--	--	--
	70	60	70	78	85	90	94	97	98	99	--	--	--	--
	80	60	71	79	86	92	95	97	99	--	--	--	--	--
	90	61	72	81	88	93	96	98	99	--	--	--	--	--
	99	62	74	83	90	94	97	99	--	--	--	--	--	--
50	50	59	69	77	84	89	93	96	98	99	--	--	--	--
	60	60	70	78	85	90	94	97	98	99	--	--	--	--
	70	60	71	79	86	92	95	97	99	--	--	--	--	--
	80	61	72	81	88	93	96	98	99	--	--	--	--	--
	90	62	74	83	90	95	97	99	--	--	--	--	--	--
	99	63	75	85	92	96	98	99	--	--	--	--	--	--
60	60	60	71	79	86	92	95	97	99	--	--	--	--	--
	70	61	72	81	88	93	96	98	99	--	--	--	--	--
	80	62	74	83	90	95	97	99	--	--	--	--	--	--
	90	63	75	85	92	96	98	99	--	--	--	--	--	--
	99	65	78	88	94	97	99	--	--	--	--	--	--	--
70	70	62	74	83	90	95	97	99	--	--	--	--	--	--
	80	63	75	85	92	96	98	99	--	--	--	--	--	--
	90	65	78	88	94	98	99	--	--	--	--	--	--	--
	99	67	81	91	96	99	--	--	--	--	--	--	--	--
80	80	65	78	88	94	98	99	--	--	--	--	--	--	--
	90	67	82	91	96	99	--	--	--	--	--	--	--	--
	99	70	86	95	99	--	--	--	--	--	--	--	--	--
90	90	71	86	95	99	--	--	--	--	--	--	--	--	--
	99	77	93	99	--	--	--	--	--	--	--	--	--	--
99	99	96	99	--	--	--	--	--	--	--	--	--	--	--

1/ Dashes indicate probability over 99 percent.

TABLE 4.--Denominators used in computing exact probabilities that one bull is superior to another

Sum of Repeatabilities 1 and 2	Denominators			Sum of Repeatabilities 1 and 2	Denominators		
	Milk yield		Fat yield		Milk yield		Fat yield
	Ayrshire Guernsey Jersey	Holstein Brown Sw.	All breeds		Ayrshire Guernsey Jersey	Holstein Brown Sw.	All breeds
Percent	Pounds	Pounds	Pounds	Percent	Pounds	Pounds	Pounds
35	514	706	25.7	125	346	476	17.3
40	506	696	25.3	130	335	460	16.7
45	498	685	24.9	135	322	443	16.1
50	490	674	24.5	140	310	426	15.5
55	482	662	24.1	145	297	408	14.8
60	473	651	23.7	150	283	389	14.1
65	465	639	23.2	155	268	369	13.4
70	456	627	22.8	160	253	348	12.6
75	447	615	22.4	165	237	325	11.8
80	438	602	21.9	170	219	301	11.0
85	429	590	21.4	175	200	275	10.0
90	420	577	21.0	180	179	246	8.9
95	410	564	20.5	183	165	227	8.2
100	400	550	20.0	187	144	198	7.2
105	390	536	19.5	190	126	174	6.3
110	379	522	19.0	192	113	156	5.6
115	369	507	18.4	195	89	123	4.5
120	358	492	17.9	198	57	78	2.8